DOCUMENT RESUME

ED 326 422 SE 051 781

AUTHOR Cox, David; Fenton, Jerry
TITLE A Discussion of Concept/Process-Based Science.
INSTITUTION Oregon State Dept. of Education, Salem.
PUB DATE Oct 90
NOTE 7p.; For a related document, see SE 051 780.
AVAILABLE FROM Oregon Dept. of Education, 700 Pringle Parkway, S.E., Salem, OR 97310-0290 (Free while supply lasts).
PUB TYPE Information Analyses (070)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Cognitive Development; *Concept Formation; *Educational Trends; *Elementary School Science; Elementary Secondary Education; Experiential Learning; Literature Reviews; *Problem Solving; Science and Society; *Science Curriculum; Science Education; Scientific Concepts; *Secondary School Science; Teaching Methods

ABSTRACT

A concept/process-based science education program is any science education program in which curriculum instruction, learning, activities, and evaluation are organized by an identified set of fundamental concepts and processes to be developed by students. This differs from science education programs that are topically based. Although topical organization is not necessarily excluded in concept/process-based science programs, such instruction should nonetheless clearly focus on the development of fundamental concepts and processes. This paper includes the following sections: (1) "What Is Concept/Process-Based Science Education?"; (2) "Why Change to Concept/Process-Based Science Programs?"; (3) "How to Understand the Science Process Skills"; (4) "How to Understand Science Concepts"; (5) "How to Facilitate Concept/Process Skill Development"; and (6) "What to Change in a Program." (KR)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
☑ This document has been reproduced as received from the person or organization originating it.
☐ Minor changes have been made to improve reproduction quality.
• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
J. T. Case
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

Oregon Department of Education
SCIENCE EDUCATION

ED326422

A SCIENCE RESOURCE PAPER

SE051781

A Discussion of

Concept/Process-Based Science

I. What is Concept/Process Based Science Education?

The Oregon Science Education Common Curriculum Goals (Oregon Department of Education, 1988) directs Oregon educators to design and implement a science curriculum that addresses seven designated science education goals. Collectively, these goals are intended to focus the science learning experiences in such a manner as *"to develop environmentally, scientifically, and technologically literate members of society"* (Oregon Department of Education, 1988, p. 2).

The first two goals of the Oregon Science Education Common Curriculum Goals (Oregon Department of Education, 1988) are:

(1) students' application of an understanding of fundamental concepts on which science is based and

(2) students' application of problem solving and inquiry skills.

These two goals of the Science Education Common Curriculum Goals are intended to be the primary organizers for the K-12 curriculum and instructional activity. The first goal regarding science concepts lists 25 concepts as fundamental, and the second goal regarding science processes and inquiry lists 15 process skills as fundamental (Oregon Department of Education, 1988, p. 3).

Because of the curricular and instructional emphasis on key concepts and processes, the Oregon Science Education Common Curriculum Goals represents an attempt to shift Oregon science education to a "concept/process-based approach". A concept/process based science education program is any science education program in which curriculum, instruction, learning activities, and evaluation are organized by an identified set of fundamental concepts and processes to be developed in students. This differs from science education programs which are topically based. Although topical organization is not necessarily excluded in concept/process- based science programs, such instruction should nonetheless clearly focus on the development of fundamental concepts and processes.

II. Why Change to Concept/Process Based Science Programs?

Three sources are pushing science educators toward concept/process-based science programs. First, national educational studies and reports (e.g., Boyer, 1983; National Commission on Excellence in Education, 1983; the National Science Board Commission on Precollege Education in Mathematics, Science and Technology, 1983) have criticized the poor quality and quantity of science education. Second, recommendations and suggestions for needed improvements in science education also come from professional organizations (e.g., NSTA, 1989). And third, research from the cognitive sciences is providing a clearer understanding of the role of students thus allowing programs to be designed which take into account students' development of concepts and processes in their scientific understanding and perspectives.

Program research in science education verifies that concept/process-based science education programs respond to the current problems in science education. Concept/process-based science programs are clearly more effective than traditional textbook-based science programs in improving students' science attitudes, interests, achievement, creativity, and higher level cognitive skills, and

these findings extend across all grade levels (Holdzkom and Lutz, 1984; Bredderman, 1983; Shymansky et al., 1983; Blosser, 1985; Thomson and Voelker, 1970; Weber and Renner, 1972; Bowyer and Linn, 1978; Renner and Marek, 1988).

Concept/process-based science education programs enhance learning and skill development in other subject areas, particularly language arts and mathematics especially if the skills are developed through first-hand experiences with objects and events (Holdzkom and Lutz, 1984; Renner et al., n.d.; Wellman, 1978; Bredderman, 1983; Shymansky, 1983; Mechling and Oliver, 1983). Concept/process-based science education programs increase the long term retention (in terms of years) of science concepts and process skills. This retention is especially significant compared to the short "life expectancy" (eight weeks) of the majority of rote learned material that is not used regularly (e.g., Montgomery, 1969; Bowyer and Linn, 1978; Cox, 1982).

And science programs which are locally developed have also been shown to be as effective or better in students' cognitive and affective performances when compared to national curricula (Aikenhead, 1980; Harknesss and Norton, 1981; Cox, 1982; Rawers and Cox, 1983).

The general conclusion is that science education should and is moving away from a singular focus on isolated traditional science content and textbook bound instruction toward an emphasis on concepts and process skills. Current efforts are now directed to balancing several aspects--process skill development, concept development, practical application, and science in the context of society (STS).

III. How to Understand the Science Process Skills

The processes emphasized in the Science Education Common Curriculum Goals are those "intellectual skills which students use in the classroom as they collect and interpret data" to successfully engage in science (Tobin and Capie, 1980, p. 590; see also Commission on Science Education, 1970). The process skills consist of two categories. The first nine--observing, using space-time relationships, classifying, using numbers, measuring, communicating, predicting, inferring, and questioning--are those which are basic and foundational for later, more complex skills, and their development progresses during the primary grades. A second category of six process skills--controlling variables, interpreting data, formulating hypotheses, defining operationally, experimenting, and formulating models--are "integrated" skills which are more complex and should be emphasized in the intermediate grades (Commission on Science Education, 1970; Showalter et al., 1974; Nay, 1981; Harlen, 1985).

The science process skills are of foundational value to learners in order to successfully engage in science. They also contribute to achievement in other academic areas and outside the formal school setting. The process skills continue to develop in learners even without the benefit of formal science instruction, and are long-lived in that they do not show the same rate of loss as with rote learned material.

IV. How to Understand Science Concepts

Concepts are mental constructs that serve as organizers for groups of objects, phenomena, events, conditions, etc. and are usually designated by one or two word descriptors (Cox, 1987). They are "the meanings attached to scientific terms" (Duxbury, 1985, p. 85) or are "a person's organized information about one or more entities--objects, events, ideas, or processes--that enable the individual to discriminate the particular entity or class of entities and also to relate it to other entities and classes of entities" (Klausmier, 1985, p. 276). Examples of concepts are 'bird', 'tree', 'planet', 'volcano', 'cycle', 'gradient', 'energy-matter', and 'symmetry'.

Science concepts serve as perceptual organizers, facilitate communication, and are the building blocks of conceptual frameworks. Concepts are transferable and enhance the meaning of prin-

ciples, generalizations, and laws. Therefore, concepts are important because they provide a framework for meaningful learning by connecting new information to the cognitive structure. And they represent the basic operational units of the cognitive domain.

Novak (1979) suggests that, *"In the past decade or two, philosophers of science...have moved increasingly toward a consensus that concepts are the most important aspect of knowledge..."* Renner and Marek (1988) state that, *"Our belief is that knowledge is constructed by the abstracting concepts from some type of experience."* Marzano and others (1988) believe that concept formation is a foundation for the other thinking processes such as comprehension, problem solving, and decision making.

V. How to Facilitate Concept/Process Skill Development

Several nationally distributed science instruction programs are process/concept based programs such as Science--A Process Approach (S-APA), Science Curriculum Improvement Study (SCIS), and Elementary Science Study (ESS). Some common characteristics of concept/process-based science programs are:

1. They emphasize the use of concrete, hands-on experiences.
2. They coordinate closely-spaced multiple learning experiences involving the concept.
3. They draw upon multiple learning contexts from a variety of disciplines and settings.
4. They make available both positive and negative examples of concepts.
5. They emphasize the use of operational definitions of concepts.
6. They maximize the students' use of the concept in language, both written and oral, and consistently demonstrate proper vocabulary with the concept.
7. They focus learning experiences specifically on the concepts or processes.
8. They provide many opportunities to apply concepts and processes to familiar settings.
9. They relate concepts to other similar ideas.
10. They are aware of the long-term development needed to produce learners' confident, independent use of concepts.
11. Their teaching practices provide wait time both before and after students' responses to instructional questions.
12. Their teaching practices provide ongoing feedback to learners regarding their progress.
13. Their teaching practices establish organization, structure, objectives, sequence, and break down the desired objective into specific knowledge and skill components by task analysis.

For example, if the process skill to be taught is observing, four components of the skill can be identified:

(1) using all appropriate senses when observing,
(2) differentiating observations and inferences,
(3) making quantitative observations and measurements when possible, and
(4) extending the senses such as by use of a magnifying glass or stethoscope.

In a collection of hands-on activities over a week or two, learners are assisted in the development of the skill by the teacher constantly interacting and providing feedback and guidance to students. Students complete self-administered progress checks which are an integral part of the sequence of learning activities.

The formation of useful concepts depends on cognitive development. Concrete experiences with the real things which will be conceptualized (e.g., mother, father, house, dog, tree) are also necessary as are activities involving the abstraction of common, shared attributes of the elements. Other important aspects of this model include conceptualizing non-examples and social interaction such as with teachers and students regarding the logic and use of the concept. The labeling or 'languaging' of the concept, which is part of the social aspect, is also necessary and serves both as a communication function and as an element for thought regarding the concept. Science concepts therefore

depend on both developmental factors internal to students and external factors of social interaction, language, and physical experiences of activity with concrete objects.

Concepts are mental constructions which represent something in its absence and make possible the description of a large number of phenomena; concepts allow predictions to be made and they make representation and communication possible. To facilitate concept development, concept/process-based science education programs use some form of instructional cycling such as the 'learning cycle' (Renner and Marek, 1988), the 'Klausmeier Model' (Marzano et al., 1988), and the 'Generative Learning Model (GLM)' (Osborne and Freyberg, 1988). Since the conceptualization process involves a cognitive construction by learners out of the factors mentioned above, instructional cycling is a necessary means for replacing learners' misconceptions with more valid ones.

VII. What To Change in a Program

To change a content oriented science education program to a concept/process-based science education program, several changes must be made:

1. Goals, philosophy, and objectives must be specifically related to the science process skills and concepts.
2. The science curriculum must be re-organized and re-structured to facilitate the development of process skills and concepts.
3. Instructional materials and learning experiences must be changed to facilitate the development of concepts and processes.
4. Teaching strategies and the instructional model must be changed to facilitate the development of the process skills and concepts.
5. Evaluation must shift its focus to the development of science process skills and concepts.

REFERENCES

Aikenhead, Glen S. 1980 "An Integrated Course Concerning the Nature, Processes, and Social Aspects of Science." In **World Trends in Science Education**. Edited by Charles P. McFadden. Halifax, N.S., Canada: Atlantic Institute of Education.

Blosser, Patricia E. 1985. **ERIC/SMEAC Science Education Digest No. 2: Research Related to Instructional Materials for Science.** Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education.

Bowyer, Jane B. and Linn, Marcia C. 1978. "Effectiveness of the Science Curriculum Improvement Study in Teaching Scientific Literacy." **Journal of Research in Science Teaching** 15 (May): 209-219.

Boyer, Ernest L. 1983. **High School: A Report on Secondary Education in America**. New York: Harper & Row Publishers.

Bredderman, Ted. 1983. "Effects of Activity-based Elementary Science on Student Outcomes: A Quantitative Synthesis." **Review of Educational Research** 53 (Winter): 499-518.

Commission on Science Education of the American Association for the Advancement of Science. 1970. **Science--A Process Approach, Commentary for Teachers.** Washington, DC: American Association for the Advancement of Science and Xerox Corp.

Cox, David C. 1987. Paper presented at Science Curriculum and Assessment Project Workshop-Conference at Silver Falls Conference Center, Sublimity, OR.

Cox, David Charles. 1982. "The Effects of Type of Classroom Science, Grade Level, Years Without Science Instruction, and Elective Science Courses on Performance Level for Selected High School Science Process Skill Competencies." Ph.D. dissertation, The Ohio State University.

Duxbury, Alyn (ed.) 1985. **Guidelines for Science Curriculum in Washington Schools**. Olympia, WA: Office of the Superintendent of Public Instruction.

Harkness, Jon L. and Norton, Daniel P. 1981. "The Developmental History and a Review of Related Research for a Validated High School Unified Science Curriculum." Wausau, WI: School District of Wausau.

Harlen, Wynne (ed.) 1985. **Primary Science, Taking the Plunge**. London: Heinemann Educational Books. A teachers handbook focusing on the full scope of elementary science teaching--rationale, content, process skills, concepts, and strategies.

Holdzkom, David and Lutz, Pamela B. (eds.) 1984. **Research Within Reach: Science Education.** Washington, DC: National Science Teachers' Association. A recent publication badly needed in the science education community. This very readable book summarizes the research findings and implications in the important science education areas of curriculum and goals, teaching and learning, influence of school and home factors on learning, and science teacher preparation/ professional development.

Klausmeier, Herbert J. 1985. **Educational Psychology**, Fifth Edition. New York: Harper & Row.

Marzano, Robert J.; Brandt, Ronald S.; Hughes, Carolyn Sue; Jones, Beau Fly; Presseisen, Barbara Z.; Rankin, Stuart C.; Suher, Charles. 1988. **Dimensions of Thinking: A Framework for Curriculum and Instruction.** Alexandria, VA: Association for Supervision and Curriculum Development.

Mechling, Kenneth R. and Oliver, Donna L. 1983. **Handbook I, Science Teachers Basic Skills.** Washington, DC: National Science Teachers Association.

Montgomery, Jerry L. 1969. "A Comparison of BSCS Versus Traditional Teaching Methods by Testing Student Achievement and Retention of Biology Concepts." Bethesda, MD: ERIC Document Reproduction Service ED 033 08901969.

National Commission on Excellence in Education. 1983. **A Nation at Risk: The Imperative for Educational Reform**. Washington, DC: U.S. Government Printing Office.

National Science Board Commission on Precollege Education in Mathematics, Science and Technology. 1983. **Educating Americans for the 21st Century.** Washington, DC: National Science Foundation.

National Science Teachers Association. 1982. **Science-Technology-Society: Science Education for the 1980's**. Washington, DC: National Science Teachers Association.

Nay, Marshall A. 1981. "How to Teach Hypothesizing and Inferencing and All That Process Stuff." Paper presented at the NSTA Area Convention, Vancouver, British Columbia, Canada, 4 (December).

Novak, Joseph D. 1979. "Implications for Teaching of Research on Learning." In **What Research Says to the Science Teacher,** Volume 2 edited by Mary Budd Rowe. Washington, DC: National Science Teachers Association, pp. 68-79. A research-based, but highly readable article discussing concepts, meaningful and rote learning, concept teaching, and cognitive functioning.

Oregon Department of Education. 1988. **Science Education Common Curriculum Goals**. Salem, OR: Oregon Department of Education.

A SCIENCE RESOURCE PAPER

Osborne, Roger and Freyberg, Peter. 1988. **Learning in Science**. Auckland, New Zealand: Heinemann Publishers. A book discussing a wide array of topics within the general area of science teaching and learning. Of special significance are chapters dealing with changing students ideas through the generative-learning model of teaching.

Rawers, Lois J. and Cox, David C. 1983. "The Science Program at Rex Putnam High School." **OSSC Bulletin** 27 (October): 1-32.

Renner, John W. and Marek, Edmund A. 1988. **The Learning Cycle and Elementary School Science Teaching**. Portsmouth, NH: Heinemann Educational Books. A teachers' handbook devoted to the learning cycle, a Piagetian-based instructional approach originally developed as the delivery system for the Science Curriculum Improvement Study (SCIS). The learning cycle has been shown to be an effective strategy for facilitating concept development.

Showalter, Victor; Cox, David; Holobinko, Paul; Thomson, Barbara; and Oriedo, Mika. 1974. "Program Objectives and Scientific Literacy." **Prism** ii 2 (Spring): 1-3 and 6-7. A multi-dimensional model for scientific literacy. Each of the proposed seven dimensions is described by a collection of factors. This article was a major reference used in the development of the Oregon Framework for Science Programs (1979).

Shymansky, James A.; Kyle, William C. Jr.; and Alport, Jennifer M. 1983. "The Effect of New Science Curricula on Student Performance." **Journal of Research in Science Teaching** 29 (May): 387-404.

Thomson, Barbara S. and Voelker, Alan M. 1970. "Programs for Improving Science Instruction in the Elementary Schools, SCIS." **Science and Children** 7 (May): 29-37.

Tobin, Kenneth G. and Capie, William. 1980. "Teaching Process Skills in the Middle School." **School Science and Mathematics** 80 (November): 590- 600.

Weber, M.C. and Renner, John W. 1972. "How Effective is the SCIS Science Program?" **School Science and Mathematics** 72 (November): 729-734.

Wellman, Ruth T. 1978. "Science: A Basic for Language and Reading Development." In **What Research Says to the Science Teacher**, Volume 1. Edited by Mary Budd Rowe. Washington, DC: National Science Teachers Association.

Oregon Department of Education
700 Pringle Parkway, SE
Salem, OR 97310-0290

John W. Erickson
State Superintendent
of Public Instruction

Oregon Schools ..... A Tradition of Excellence!

October 1990

Single copies of this document are available by contacting the documents clerk at 378-3589 or copies may be made without permission from the Oregon Department of Education.

This paper was prepared by David Cox (Education Department, Portland State University), Jerry Fenton, (Region 4 OCATS Staff Development Specialist, Science Department, Rex Putman High School, Milwaukie, OR), and edited to reflect comments from Oregon educators and selected national science education reviewers.